Using Atmosphere-Forest Flux Measurements to Examine the Potential for Reduced Downwind Dose

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Introduction

Regulatory modeling of downwind dose received due to radiological releases often use Gaussian dispersion models which do not account for how forested environments affect plume transport and dispersion, such as reduced winds peed within the forest (Figure 1) or additional turbulence at the forest top will act to increase horizontal diffusion and mix a portion of the plume into the forest airspace. This is expected to lead to decreased airborne concentrations within the plume and subsequent decreases in downwind exposure and dose to individuals affected by a radiological plume compared with models which do not account for forest effects. The goal of this work is to provide the modeling framework necessary to create appropriate deposition velocity estimates which reflect the influence of the forest on atmospheric dispersion.

Model

Wind and vertical moisture flux measured at the Aiken AmeriFlux Tower (AAT) at four levels within the forest (2m, 12m, 18m, and 25m) and one above the forest (28m) were used to drive atmospheric transport models. Moisture flux was used due to water vapor's molecular similarity to tritium oxide (Brudenell 1997; Ota and Nagai 2011).

A combination of a Gaussian dispersion model (above canopy) and a 2-D advection-diffusion model (within canopy) was used to simulate the effects of the forest on atmospheric dispersion.

- The Gaussian model was used to predict an initial plume using the forest canopy top as its lower surface limit.
- Water vapor flux data from the AAT was used to determine the rate at which material in the above-canopy Gaussian plume was deposited into the forest.
- Within-forest dispersion was modeled using vertical diffusion based on the vertical flux of water vapor (w'q') measured at the AAT at each level and horizontal advection of the plume by the mean within-canopy wind speeds measured at the AAT.
- Depletion of the Gaussian plume was accounted for by creating additional Gaussian plumes with negative sources based on the amount of deposited material at each downwind point.
- When material was predicted to move out of the forest, additional Gaussian plumes with positive sources were added to primary plume

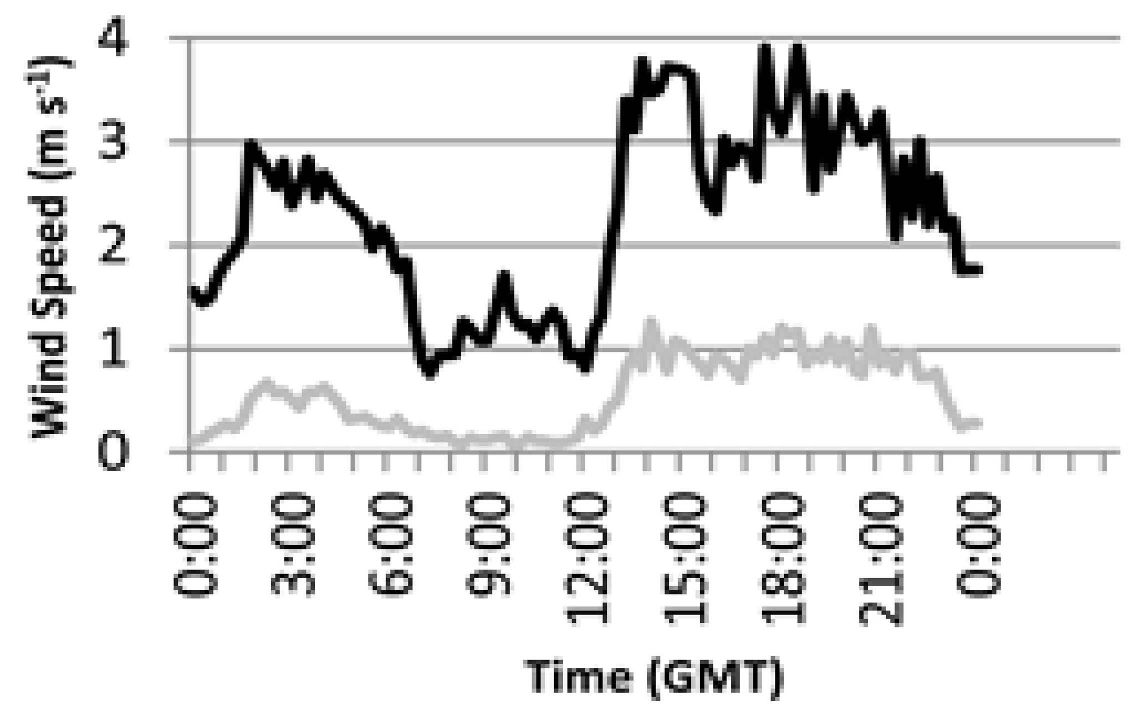

Figure 1: Example comparison of wind speed in an open field (black line) and a pine forest (gray line). This pattern is observed due to the additional drag of the forest trees slowing down the wind speed.

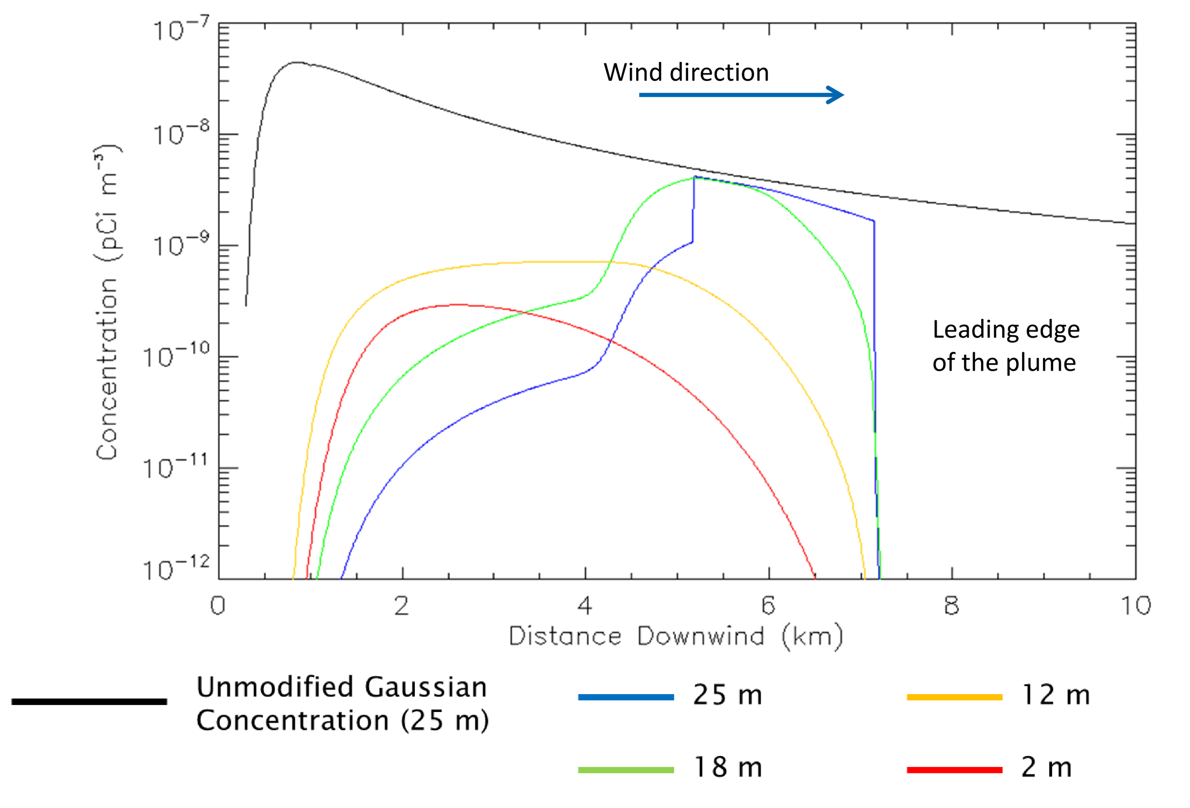

Figure 2: Airborne concentration of a plume at the forest top (25m) and within the forest) after 6000 s. The black line indicates the predicted Gaussian concentration at the forest top assuming no deposition to the forest.

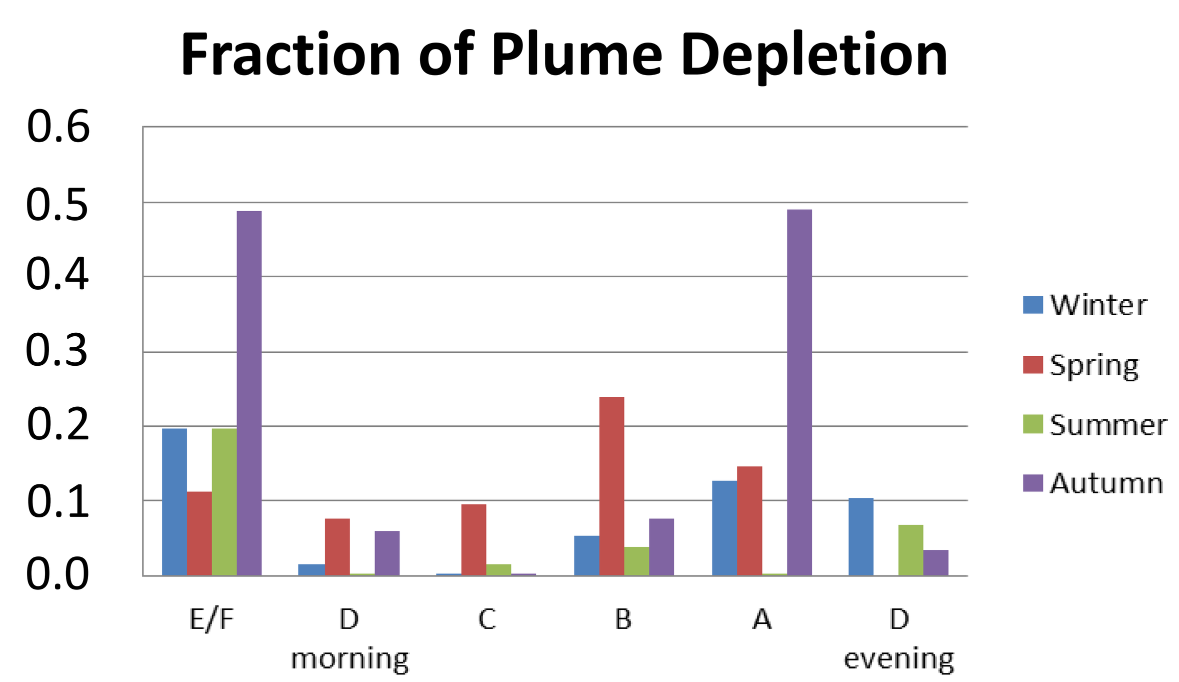

Figure 3: Fraction of the free-atmosphere plume which has been mixed into the forest environment when the plume reaches 10 km compared to a standard Gaussian prediction. The stability categories are arranged such that they generally move from night (left) to morning, afternoon and evening (right).

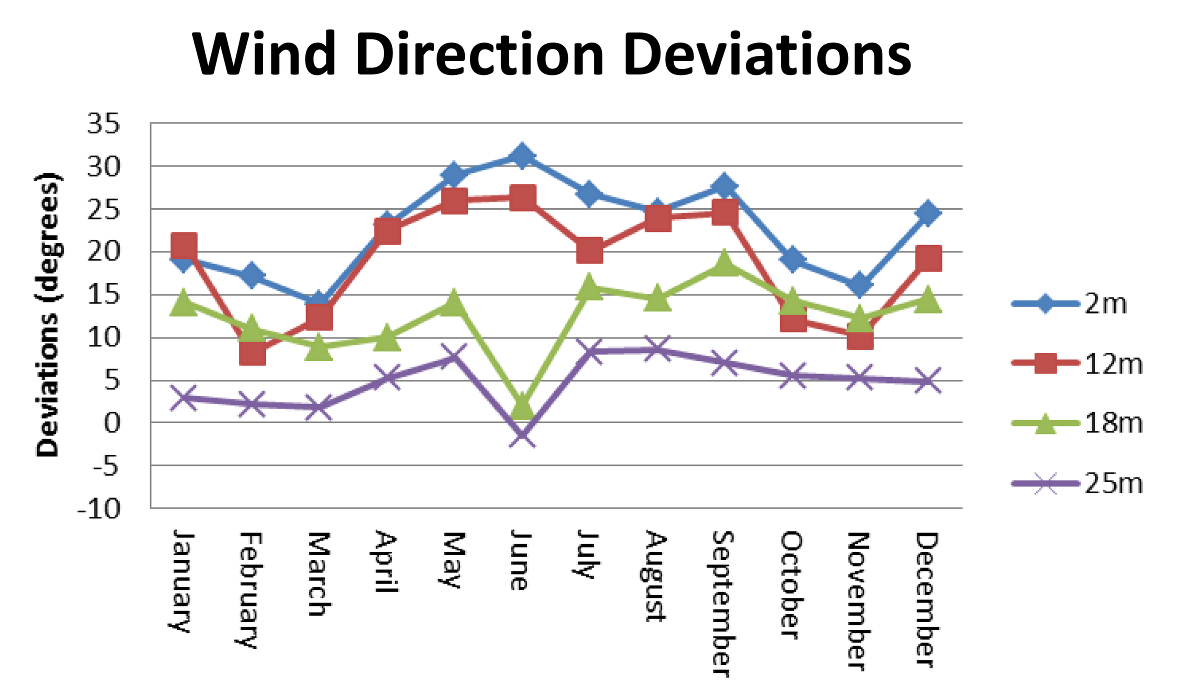

Figure 4: Average difference in wind direction between the identified level and 28 m (calculated as the Wind Direction @ 28m – the Wind Direction @ *X* m). Positive deviations indicate turning of the wind in a counter-clockwise direction while negative deviations indicate turning in a clockwise direction.

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Results

- Plume characteristics above and within the forest were evaluated 10 km from the release point (the estimated average distance between a release and the SRS boundary; Figure 2).
- A greater fraction of the plume was predicted to mix into the forest under very stable conditions (E/F Stability) or very unstable conditions (A/B Stability). Less mixing was predicted for near-neutral conditions (C/D Stability).
- Increased mixing during the day is attributed to increased turbulence during the day; the vertical convective turbulence in addition to the mechanical turbulence at the forest top combine to mix a greater fraction of the plume downward.
- In stable conditions, a narrow, highly concentrated plume constrained near the forest top creates a larger gradient between the atmosphere and forest airspace, increasing the downward flux of the plume into the forest.
- The next stage of this project is to analyze the rates of mixing into the forest under these conditions to determine the appropriate estimates deposition velocity.

Ongoing Work

Research is currently underway to expand the current model to examine:

- How will changes in wind direction (Figure 4) within the forest canopy act to further diffuse the plume in cross-wind directions relative to the primary direction of travel?
- How much would uptake by local vegetation further reduce predicted airborne plume concentrations?
- How can the current work be applied to regulatory Gaussian dispersion models which do not model the transfer between air above and within forests and alsorequire a single deposition velocity?

References

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Ota, M. and H. Nagai. 2011. Development and validation of a dynamical atmosphere-vegetation-soil HTO transport and OBT formation model. *J. Environmental Radioactivity*, **102**:813-823.